Cloud Properties from MODIS, AIRS, and MODIS/AIRS observations

S. A. Ackerman, D. Tobin, P. Anotonelli, P. Menzel

Outline

- What are we doing and why?
- MODIS and AIRS advantages and disadvantages.
- Steps to combining the two to get better retrievals.

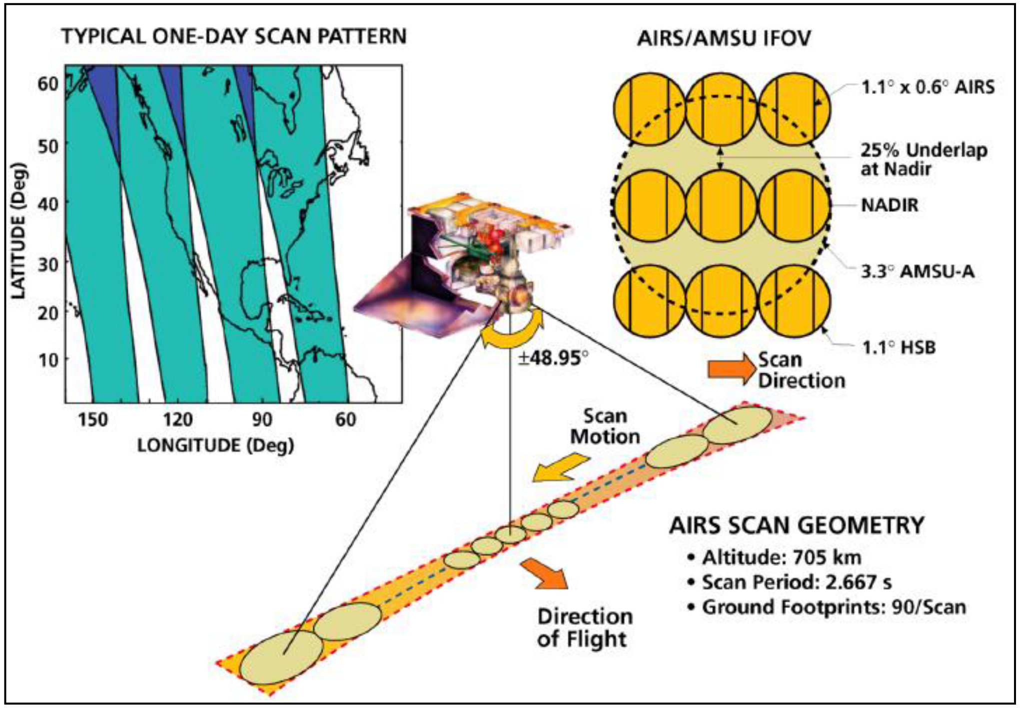
AIRS (Atmospheric Infrared Sounder) related activities at CIMSS

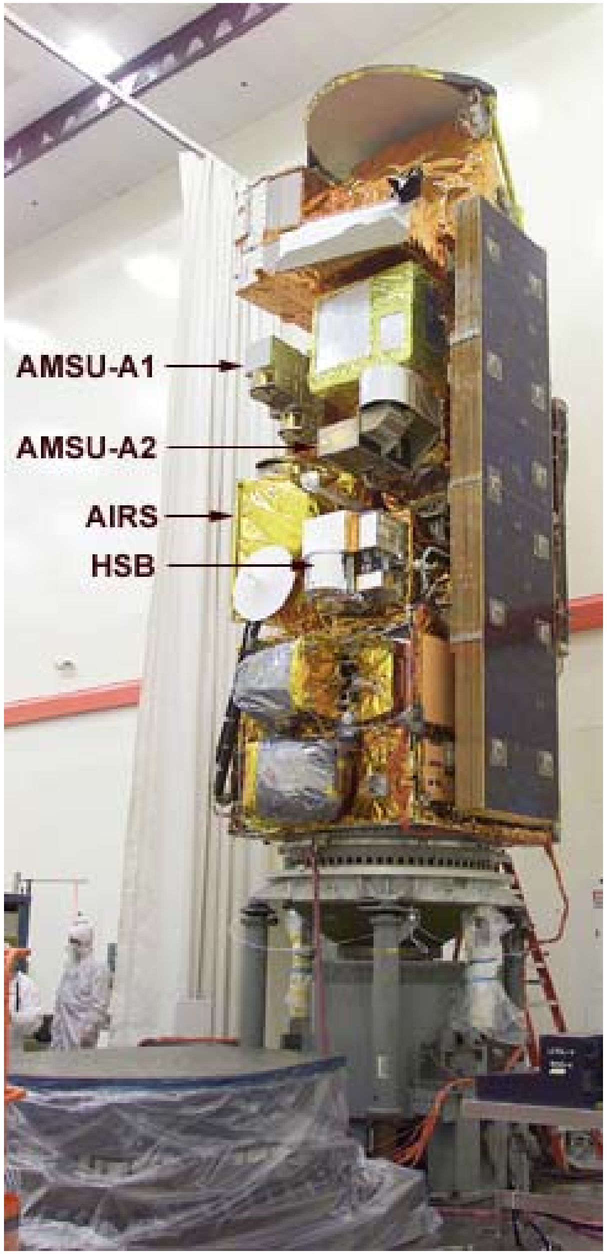
Instrument

- Hyperspectral radiometer with resolution of 0.5 – 2 cm^{-1}
- Extremely well calibrated pre-launch
- Spectral range: 650 – 2700 cm^{-1}, **2378 channels**!
- Associated microwave instruments (AMSU, HSB)

Thanks to the NASA JPL and other AIRS team member institutions.

- **AIRS** is part of the EOS Aqua instrument suite
- Managed by NASA/JPL. Mous Chahine is the Science Team Leader
- Launched from Vandenburg on May 4th 2002
- Orbit: 705 km, polar sun synchronous ascending 1:30 PM local
- Companion instruments
  - **AMSU-A** (Advanced Microwave Sounding Unit - A)
  - **HSB** (Humidity Sounder for Brazil)
  - MODIS, CERES, AMSR-E





Instrument

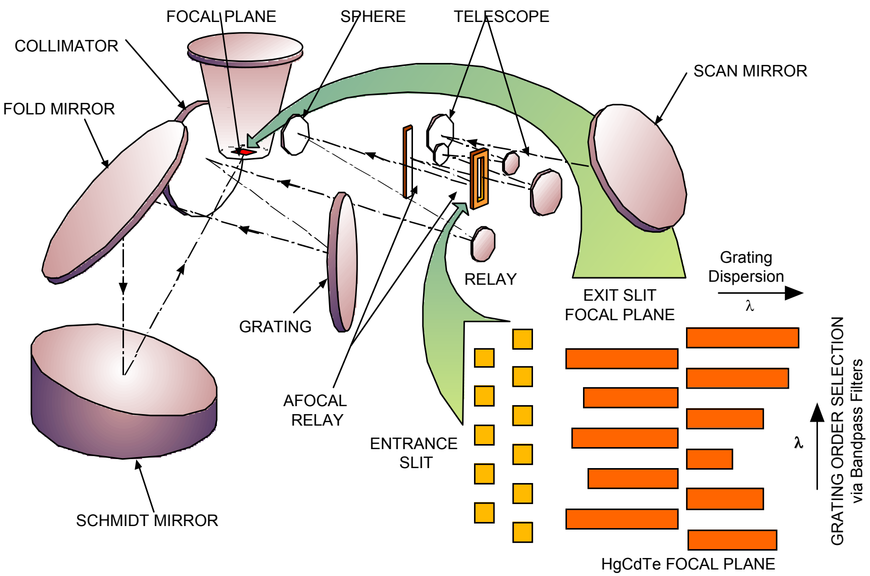
- Hyperspectral radiometer with resolution of 0.5 – 2 cm^{-1}
- Extremely well calibrated pre-launch
- Spectral range: 650 – 2700 cm^{-1}, **2378 channels**!
- Associated microwave instruments (AMSU, HSB)

Goals

- Improve medium range weather forecasting **and**
- Provide long-term climate record via
  (1) hyperspectral infrared radiances
  (2) retrieved products such as T(z), Q(z), O_3, CO, cloud properties, etc.
- Will greatly enhance soundings of temperature and humidity (1K/1km, 20%/2km)
- Has extremely "clean" SST channels in the 2600 cm^{-1} region
- Supports NOAA/NCEP's operational requirements. Data provided to assimilation centers.
- Precursor to future advanced high spectral resolution sounders (IASI, CrIS, GIFTS)

Design

- Grating Spectrometer passively cooled to 160K, stabilized to 30 mK
- PV and PC HdCdTe focal plane cooled to 60K with redundant active pulse tube cryogenic coolers
- Focal plane has ~5000 detectors, 2378 channels. PV detectors (all below 13 microns) are doubly redundant. Two channels per resolution element (n/Dn = 1200)
- 310 K Blackbody and space view provides radiometric calibration
- Paralyene coating on calibration mirror and upwelling radiation provides spectral calibration
- NEDT (per resolution element) ranges from 0.05K to 0.5K



Spectral filters at each entrance slit and over each FPA array isolate color band (grating order) of interest

Satellite Observations

Reflectance (R_λ), Transmittance (T_λ), Absorptance (A_λ)[Emittance(ε_λ)]

Temperature and Gas Incident Fluxes

Single Scattering Properties

δ_λ , ω_o , $P(\mu, \mu')$

Cloud Macrophysical properties

Cloud Microphysics

$n(r)$, $n(h)$, $m=m_r-im_i$

IWC, IWP, LWC, LWP

Dynamics and Thermodynamics

Satellite Observations → Effective Macrophysical properties

Reflectance (R_λ), Transmittance (T_λ), Absorptance (A_λ)[Emittance(ε_λ)]

Effective Microphysical properties

Single Scattering Properties

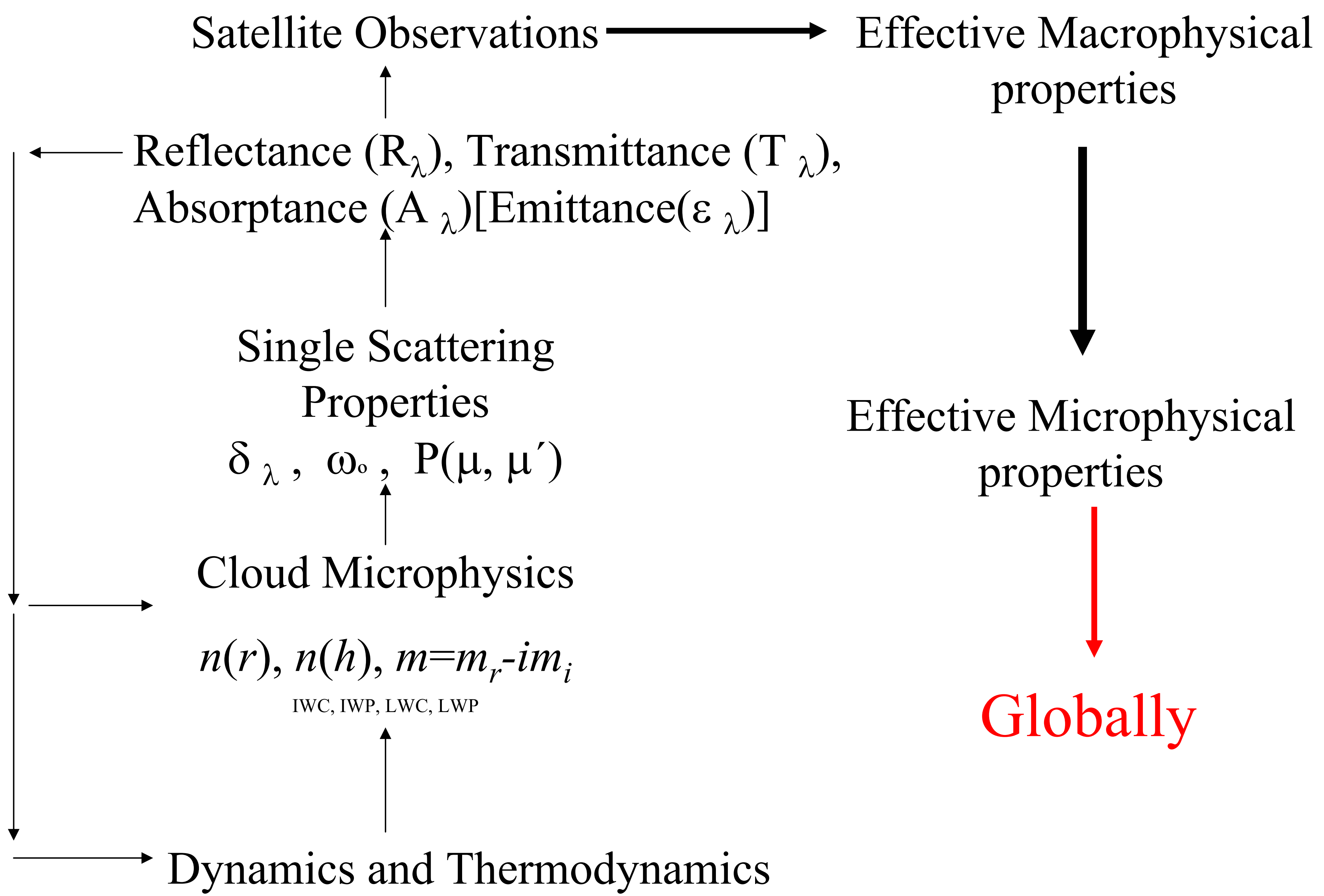
δ_λ , $\omega_\circ$, $P(\mu, \mu')$

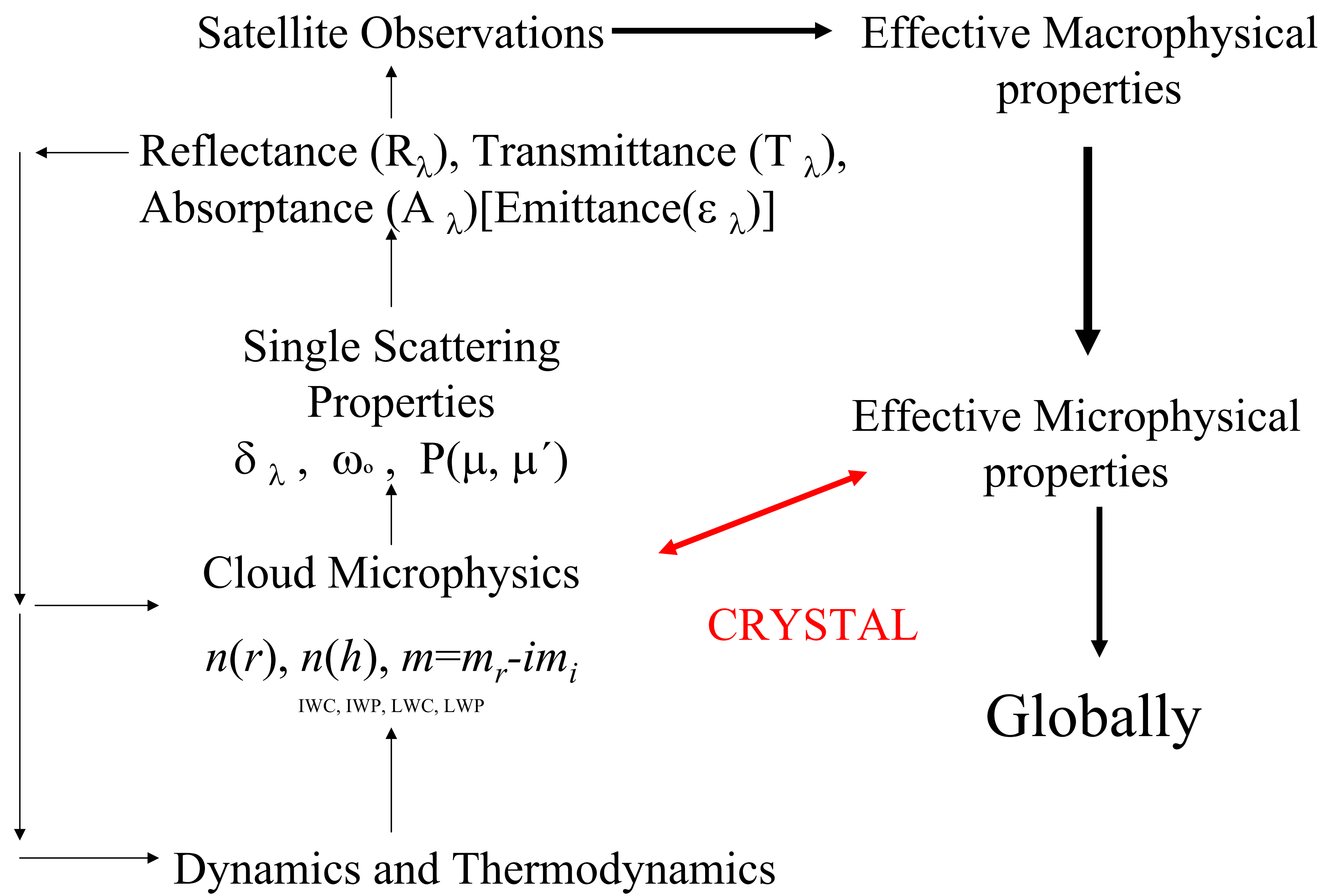
Cloud Microphysics

$n(r)$, $n(h)$, $m=m_r-im_i$

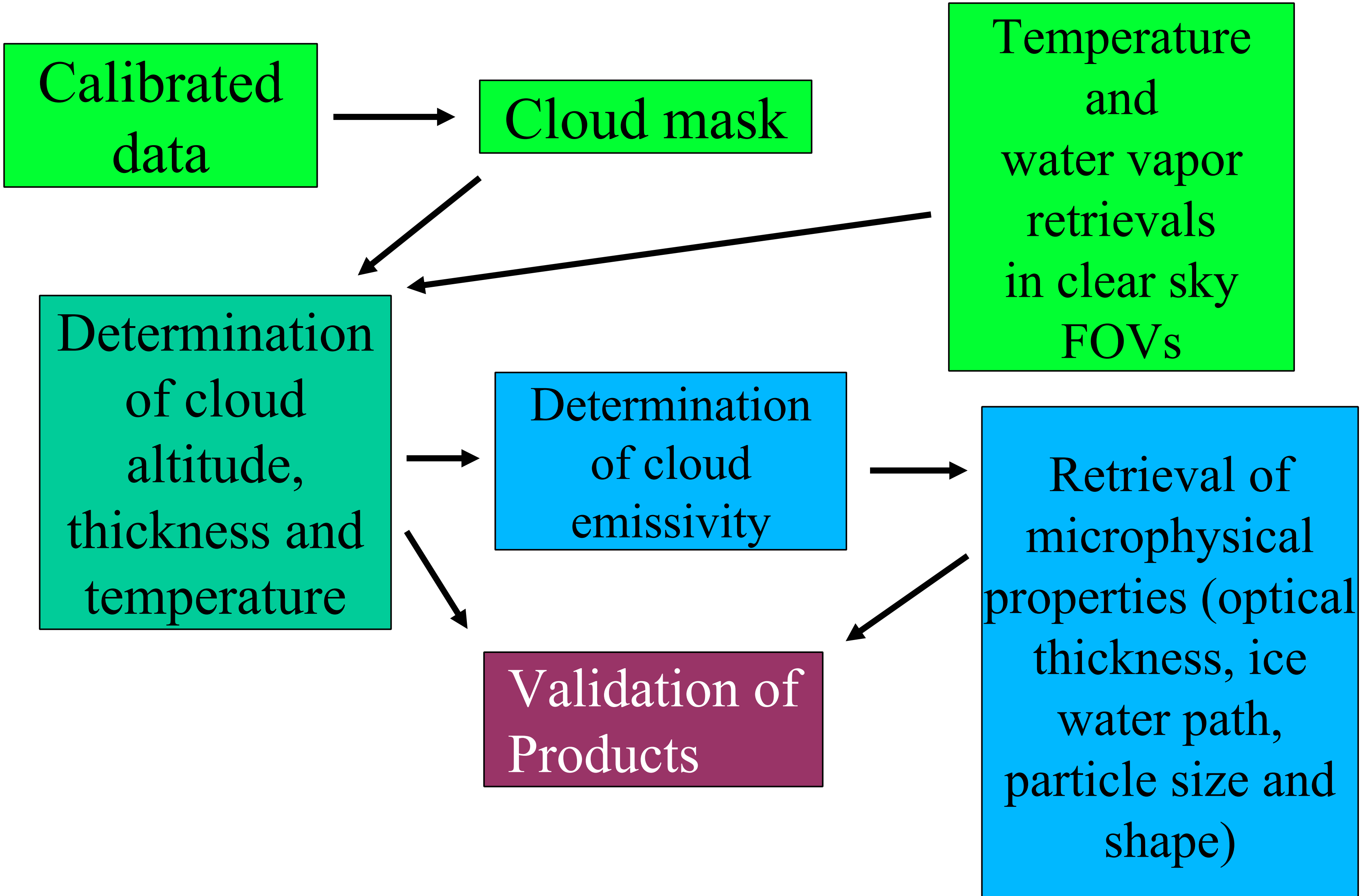
IWC, IWP, LWC, LWP

Dynamics and Thermodynamics


Satellite Observations
Effective Macrophysical properties
Reflectance (R_λ), Transmittance (T_λ), Absorptance (A_λ)[Emittance(ε_λ)]
Single Scattering Properties
δ_λ, ω_o, $P(\mu, \mu')$
Cloud Microphysics
$n(r)$, $n(h)$, $m=m_r-im_i$
IWC, IWP, LWC, LWP
Dynamics and Thermodynamics
Effective Microphysical properties
Globally


Satellite Observations
Effective Macrophysical properties
Reflectance (R_λ), Transmittance (T_λ), Absorptance (A_λ)[Emittance(ε_λ)]
Single Scattering Properties
δ_λ, ω_o, $P(\mu, \mu')$
Effective Microphysical properties
Cloud Microphysics
$n(r)$, $n(h)$, $m=m_r-im_i$
IWC, IWP, LWC, LWP
CRYSTAL
Globally
Dynamics and Thermodynamics

IR Retrieval Scheme for Clouds

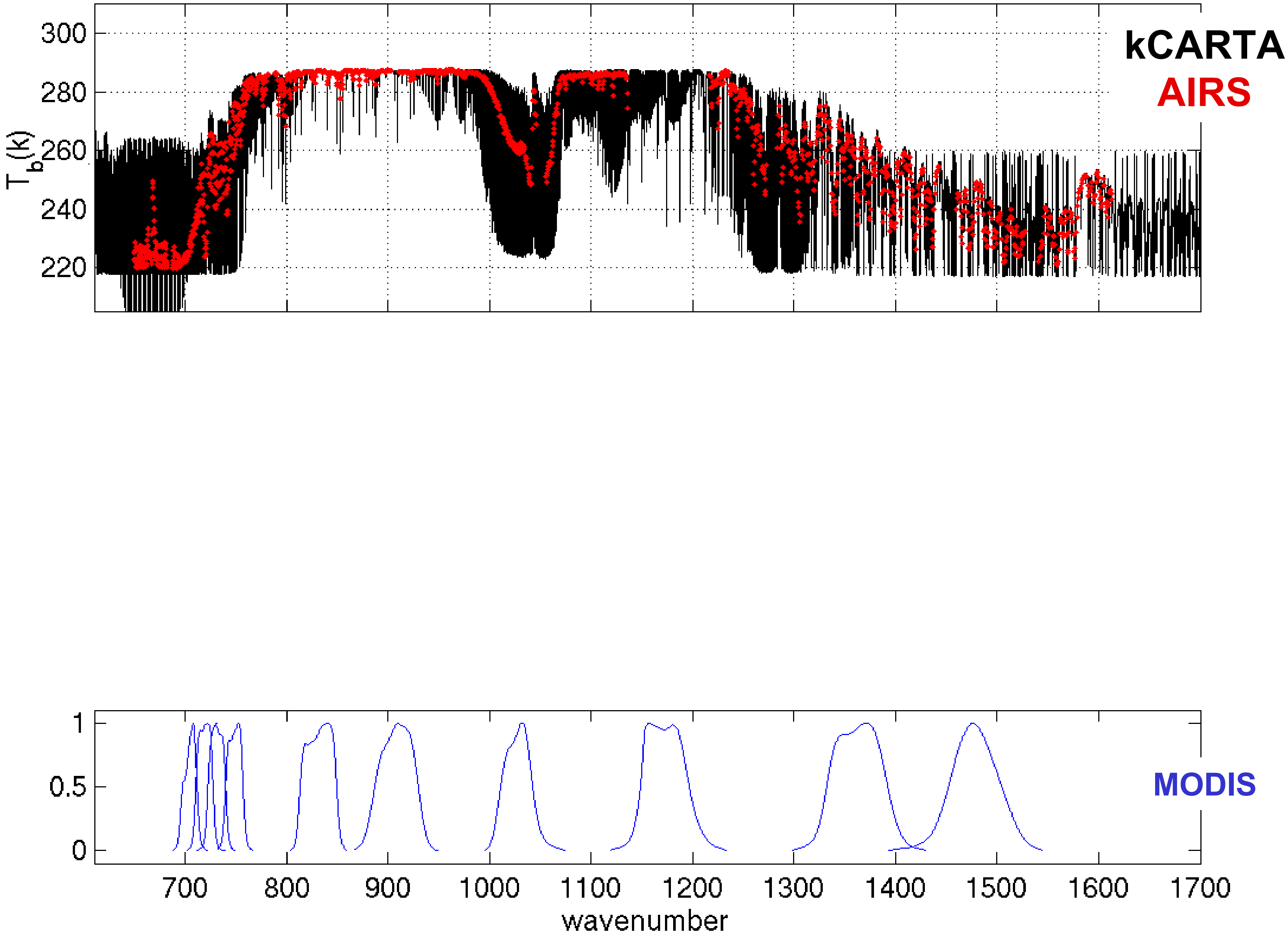


Instrument	Strength	Weakness
AIRS	High-spectral resolution capable of observing absorption lines	Large footprint (approximately 12 km to 30 km)
MODIS	Spatial resolution of 1km or better, spectral coverage from visible to infrared.	Narrowband measurements

Combining Observations

- Collocation
- Radiance Comparisons
- Product Comparisons
- Combined Retrievals

LW SRFs



kCARTA
AIRS
T_b(k)
300
280
260
240
220
MODIS
1
0.5
0
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
wavenumber

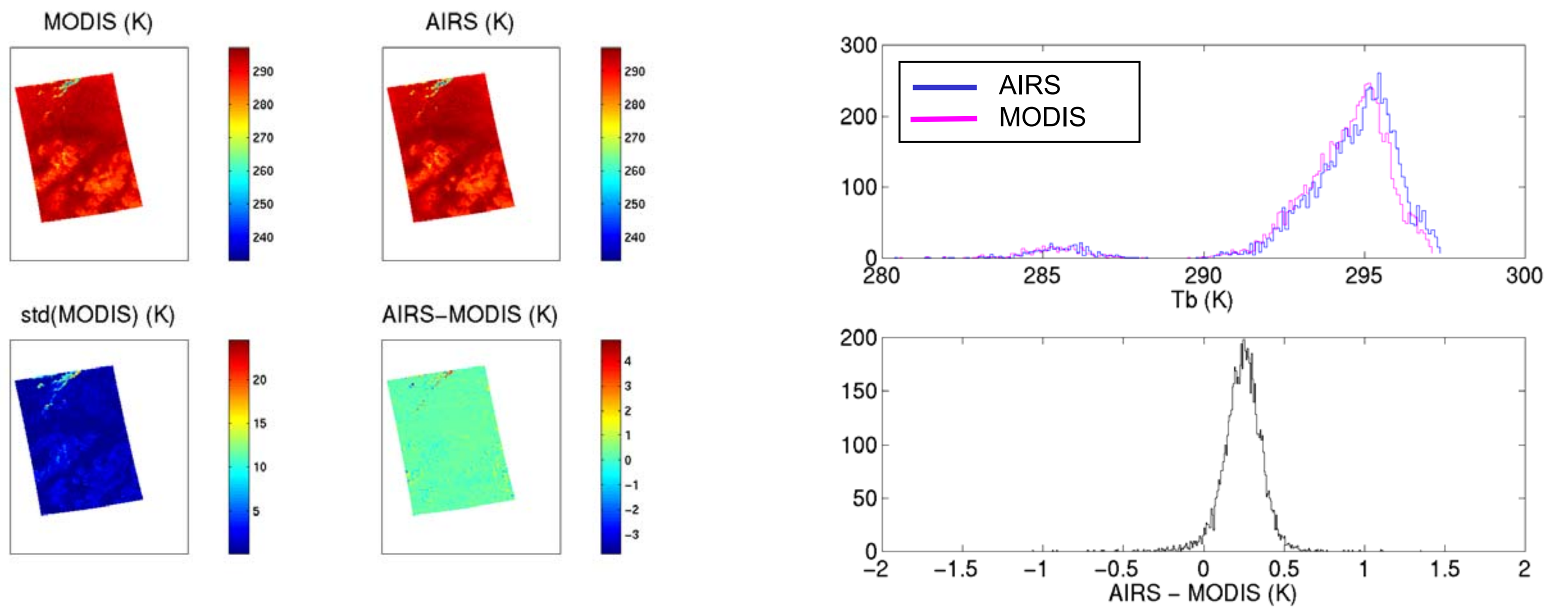
AIRS / MODIS comparisons using Tb histograms

- **Approach using Aqua MODIS and AIRS granule data**
  - convolve AIRS spectra with MODIS SRFs
  - Compute mean and variance of MODIS observations within each AIRS FOV.
  - Screen data based on cloud flag, MODIS variability, scan angles, and compare observed brightness temperatures

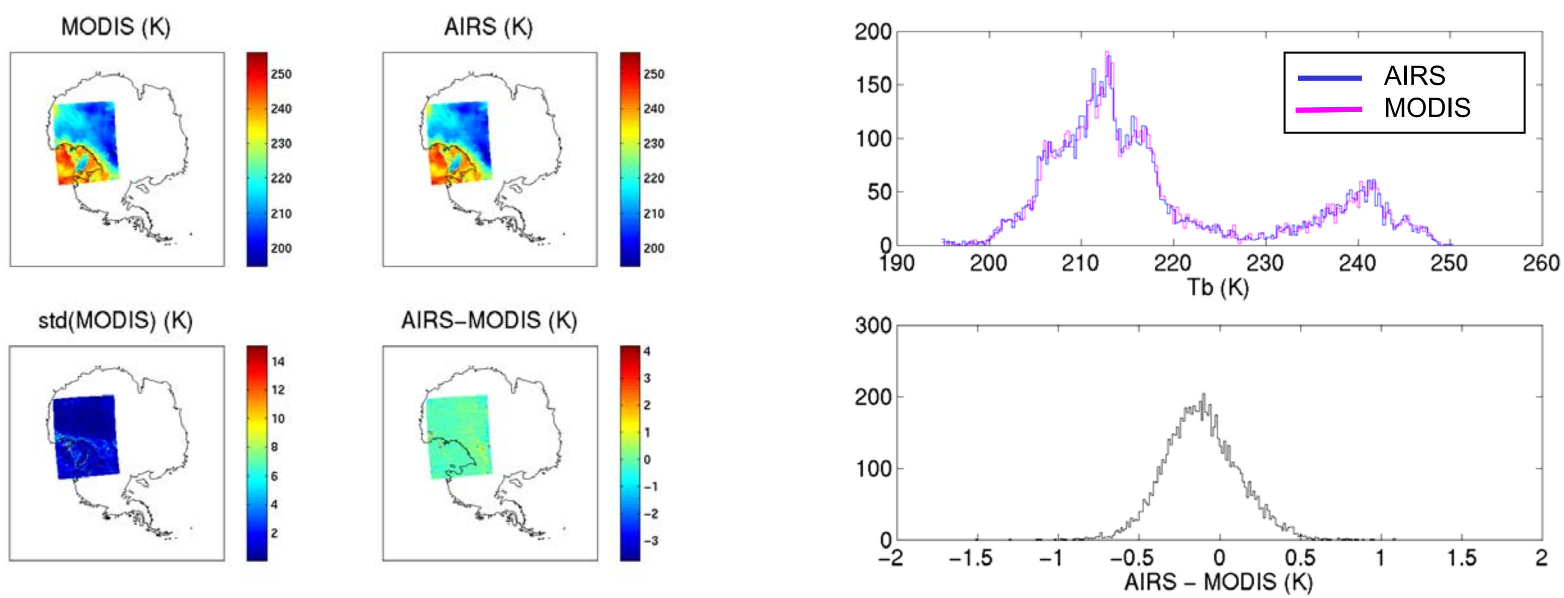
AIRS/MODIS Brightness Temperature Comparisons

20-July-2002, Band 32 (~12.0μm)

GOES-10 sub-satellite point



Dome Concordia, Antarctica



Summary:

Band	1/cm	microns	convError(K)	AIRS-MODIS (K)* 07/20/02 gran 224	07/20/02 gran 072	11/21/02 gran 196
32	830.8	12.03	-0.00	0.24	-0.12	0.06
33	748.3	13.36	0.20	0.35	0.30	-0.13
34	730.8	13.68	0.05	-0.33	-0.00	-0.27
35	718.2	13.92	0.21	-0.54	0.03	-0.77
36	703.5	14.21	0.16	-1.06	-0.34	-1.21

* Diffs include convolution error

- Preliminary analysis of AIRS/MODIS comparisons for MODIS longwave

  Bands 32 thru 35 show mean agreement to better than ~0.5K (~1K for Band 36, granules 224 and 196), with no obvious dependence on scene temperatures studied. Longwave differences increase from ~0K at band 32 to ~1K at band 36 for 07/20 granule 072 and 11/21 granule 196.

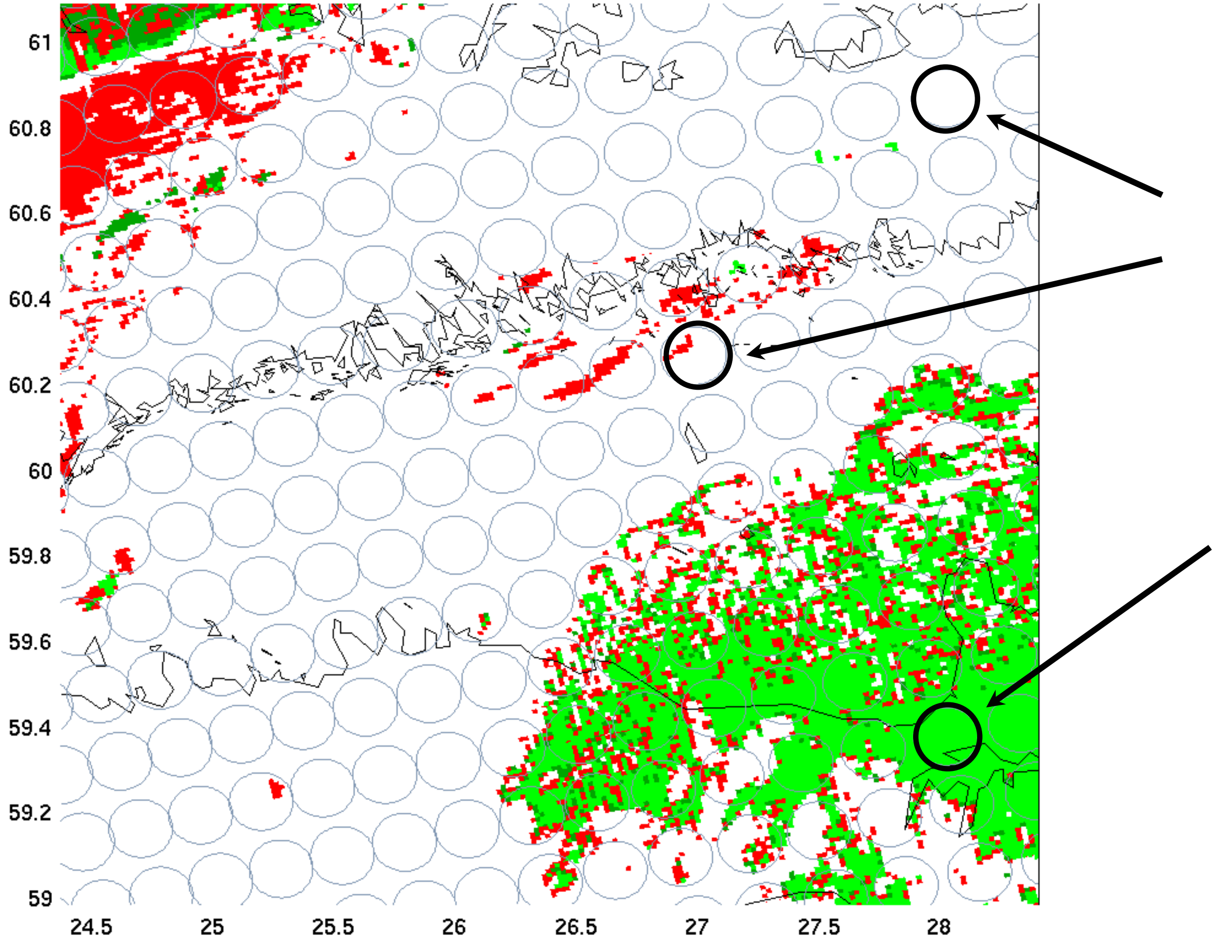
Combining Observations

- Collocation
- Radiance Comparisons
- Product Comparisons
- Combined Retrievals

Cloud detection
Cloud top pressure

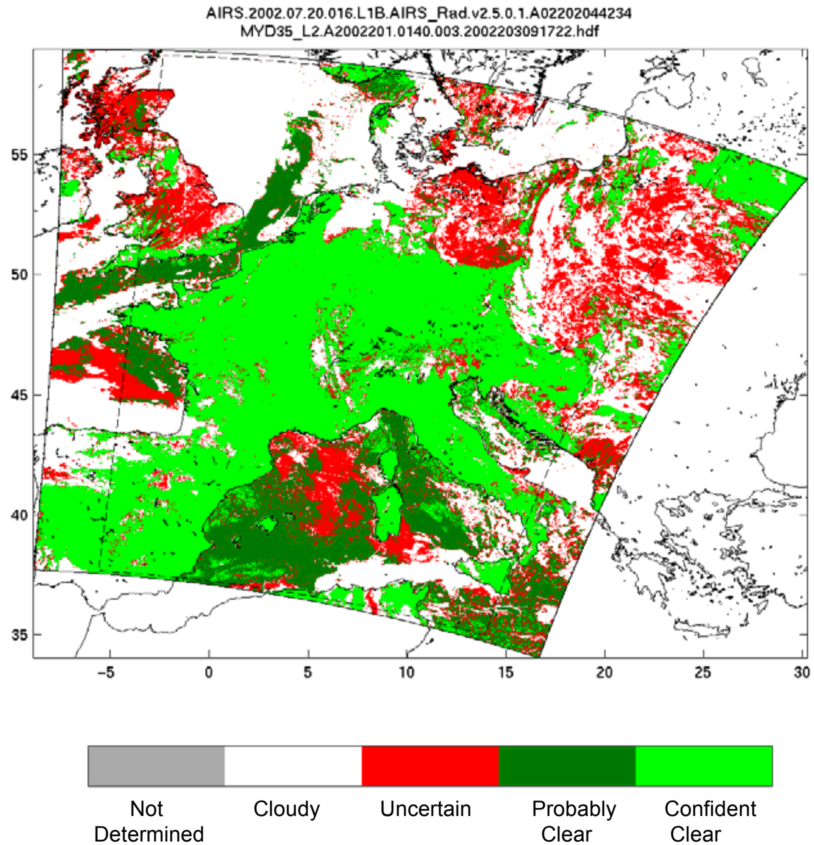
AIRS Clear Flag from MODIS cloud mask

Not Determined	Cloudy	Uncertain	Probably Clear	Confident Clear

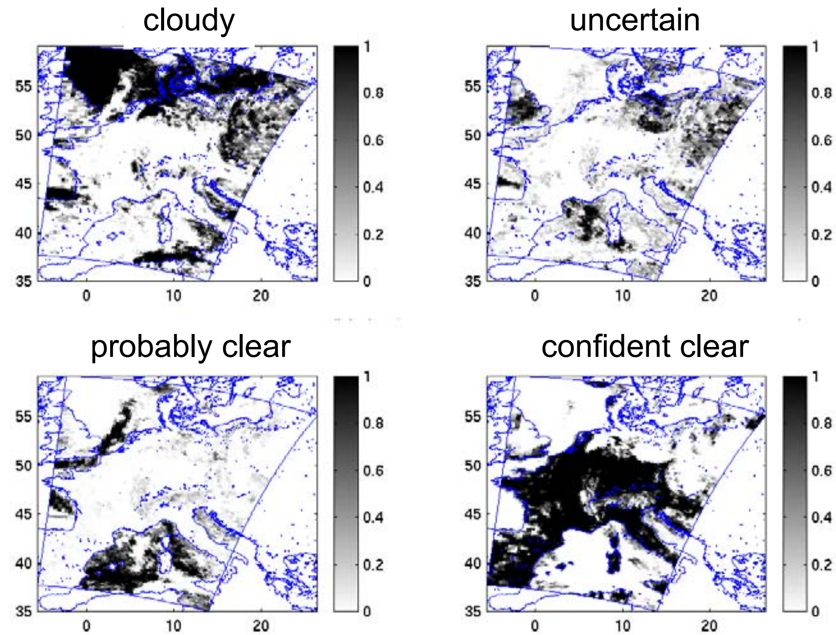


Granule 016

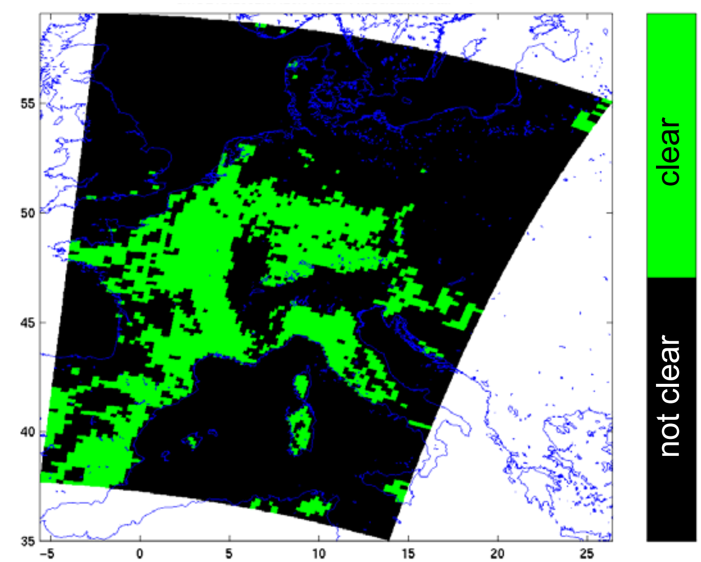
MODIS cloud mask



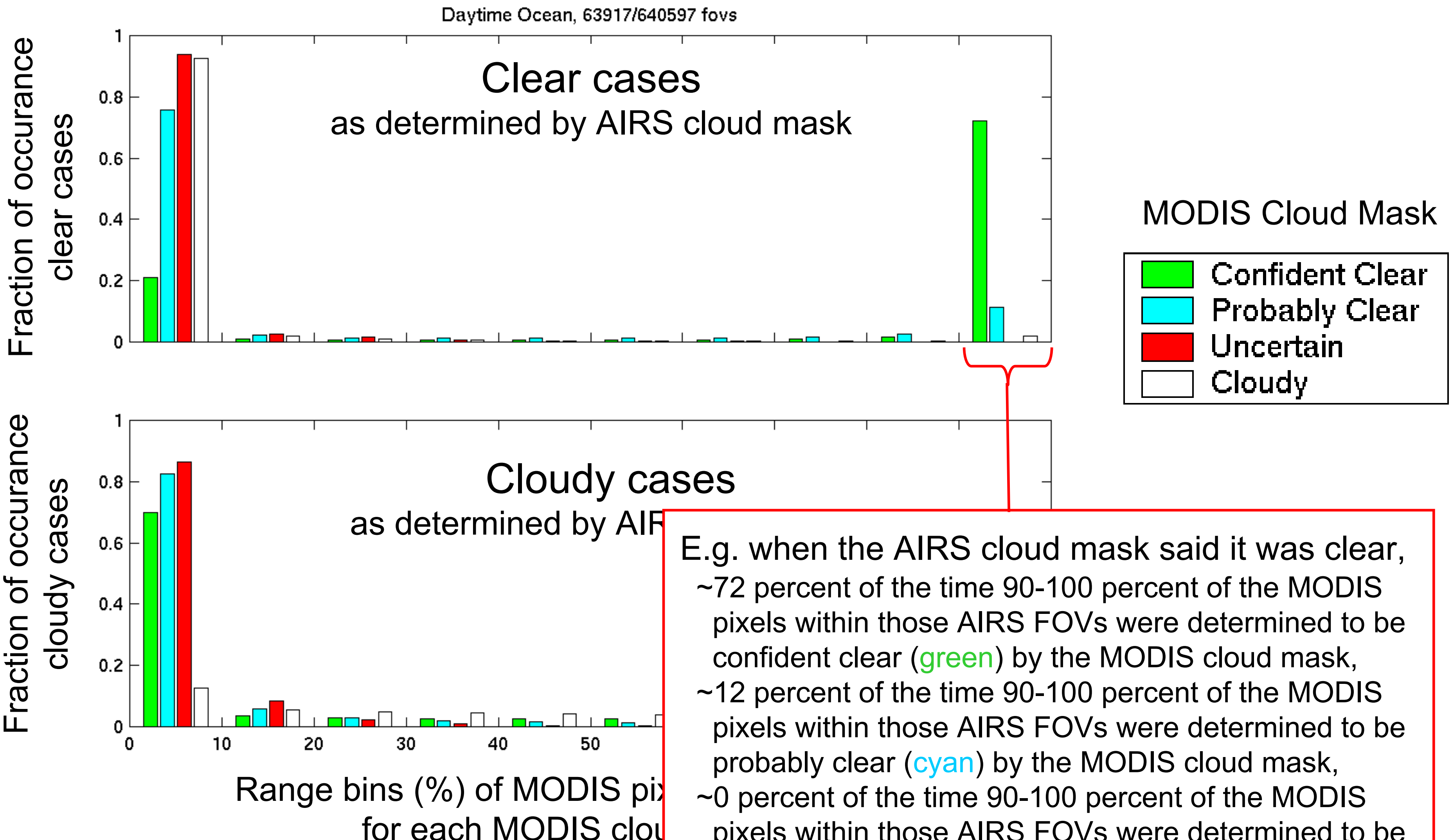
cMODIS fractions



AIRS cloud flag. All confident clear



Sample AIRS/MODIS Cloud Mask Histogram



E.g. when the AIRS cloud mask said it was clear,

- ~72 percent of the time 90-100 percent of the MODIS pixels within those AIRS FOVs were determined to be confident clear (green) by the MODIS cloud mask,
- ~12 percent of the time 90-100 percent of the MODIS pixels within those AIRS FOVs were determined to be probably clear (cyan) by the MODIS cloud mask,
- ~0 percent of the time 90-100 percent of the MODIS pixels within those AIRS FOVs were determined to be uncertain (red) by the MODIS cloud mask, and
- ~3 percent of the time 90-100 percent of the MODIS pixels within those AIRS FOVs were determined to be cloudy (white) by the MODIS cloud mask.

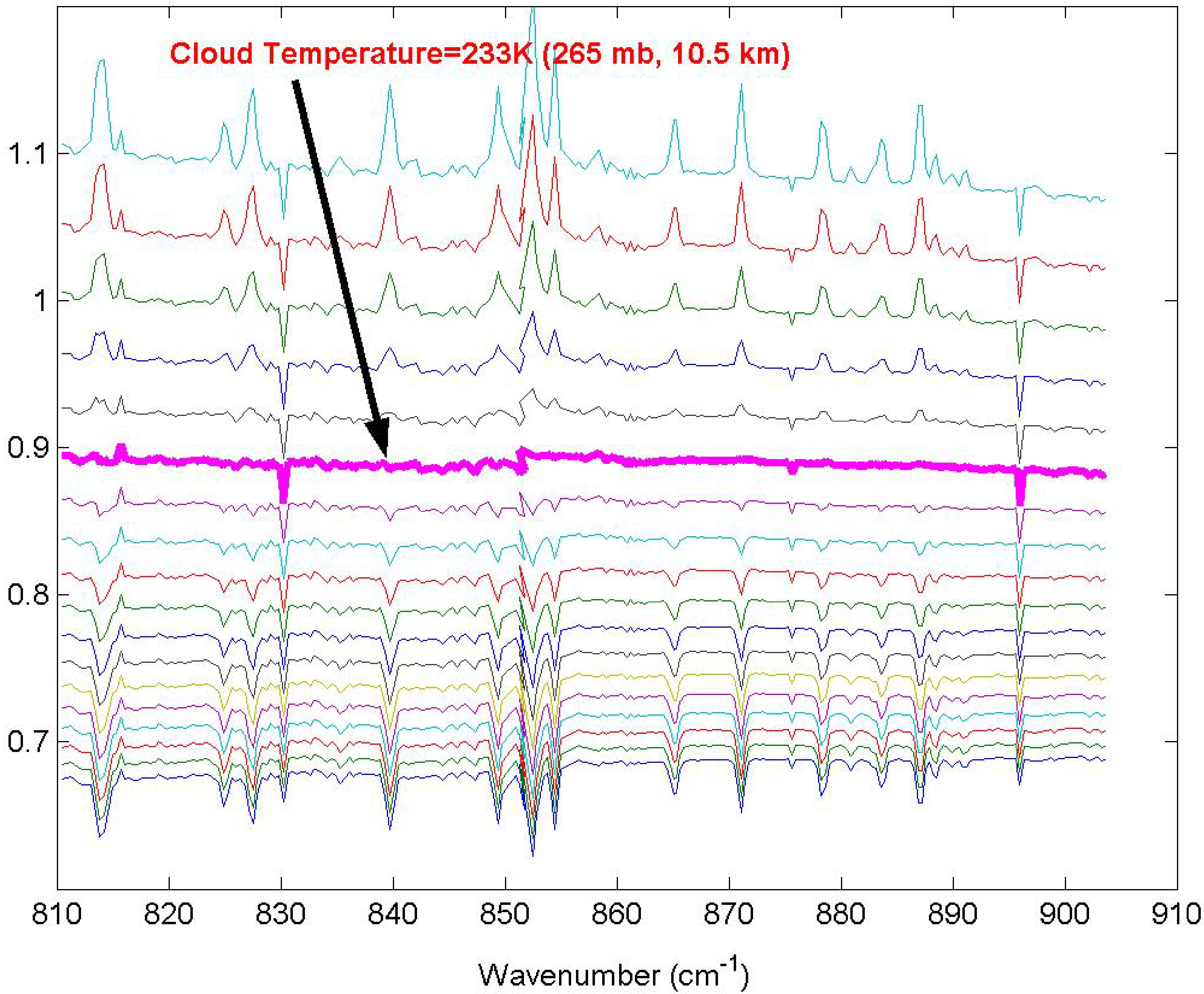
Minimum Local Emissivity Variance (MLEV)

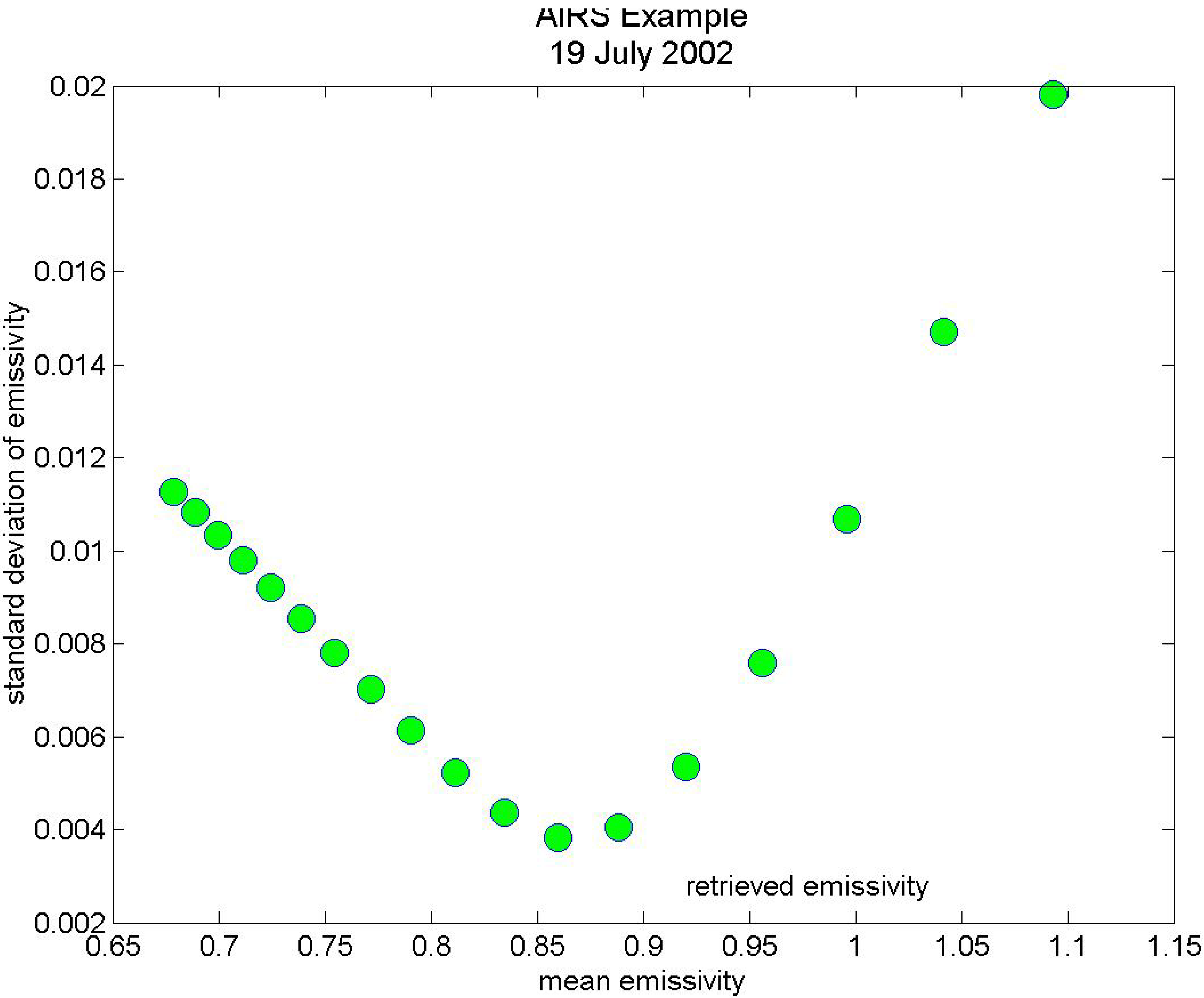
Observations between 810 and 910 cm^{-1}

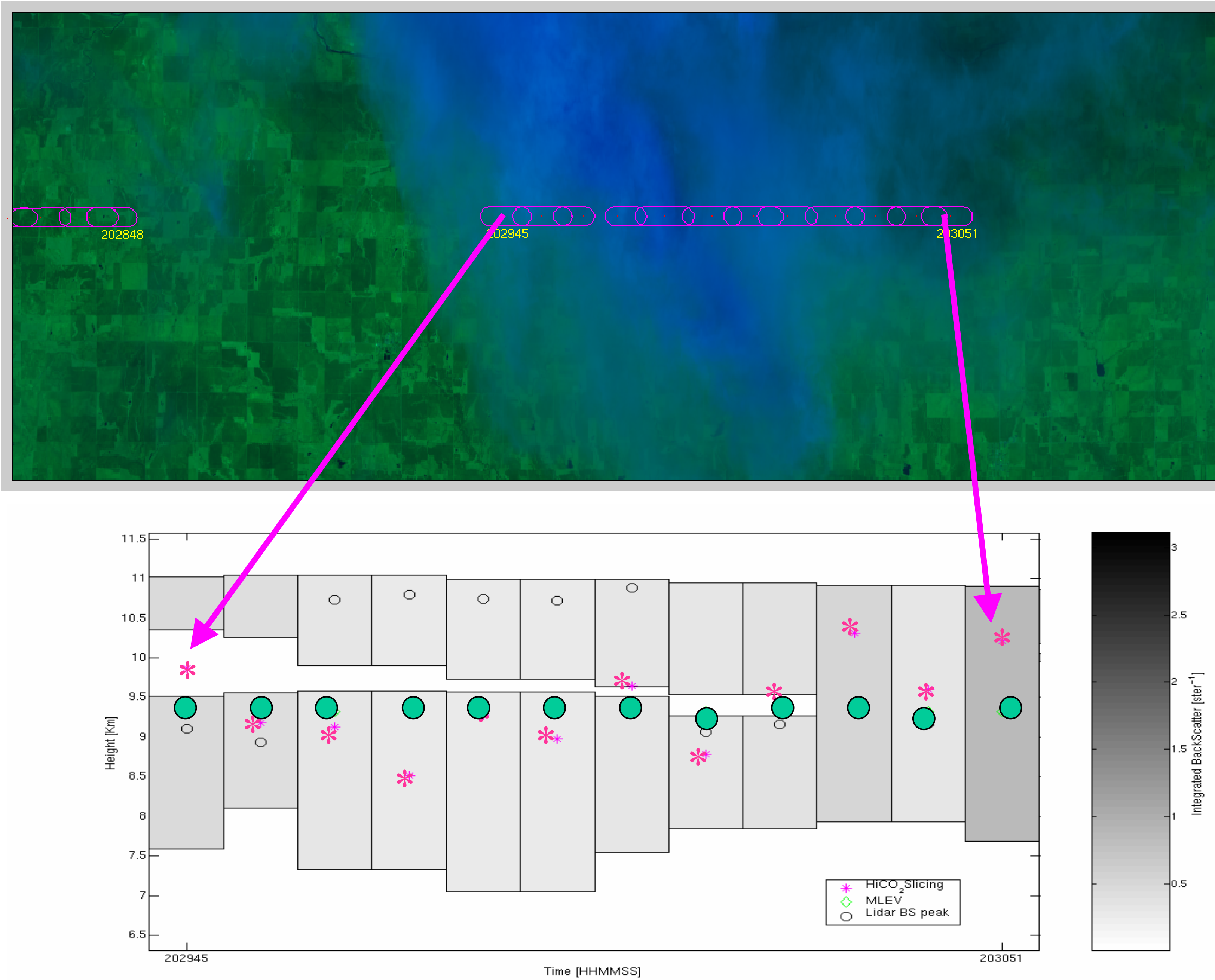
$$\varepsilon_v = \frac{I_v^{observed} - I_v^{clear}}{I_v^{cloud} - I_v^{clear}}$$

$$\varepsilon_v^{'} = \min \sum \left[\frac{\varepsilon_v - \varepsilon_v^{'}}{\varepsilon_v} \right]^2$$

19 July 2002:
AIRS Example Retreival

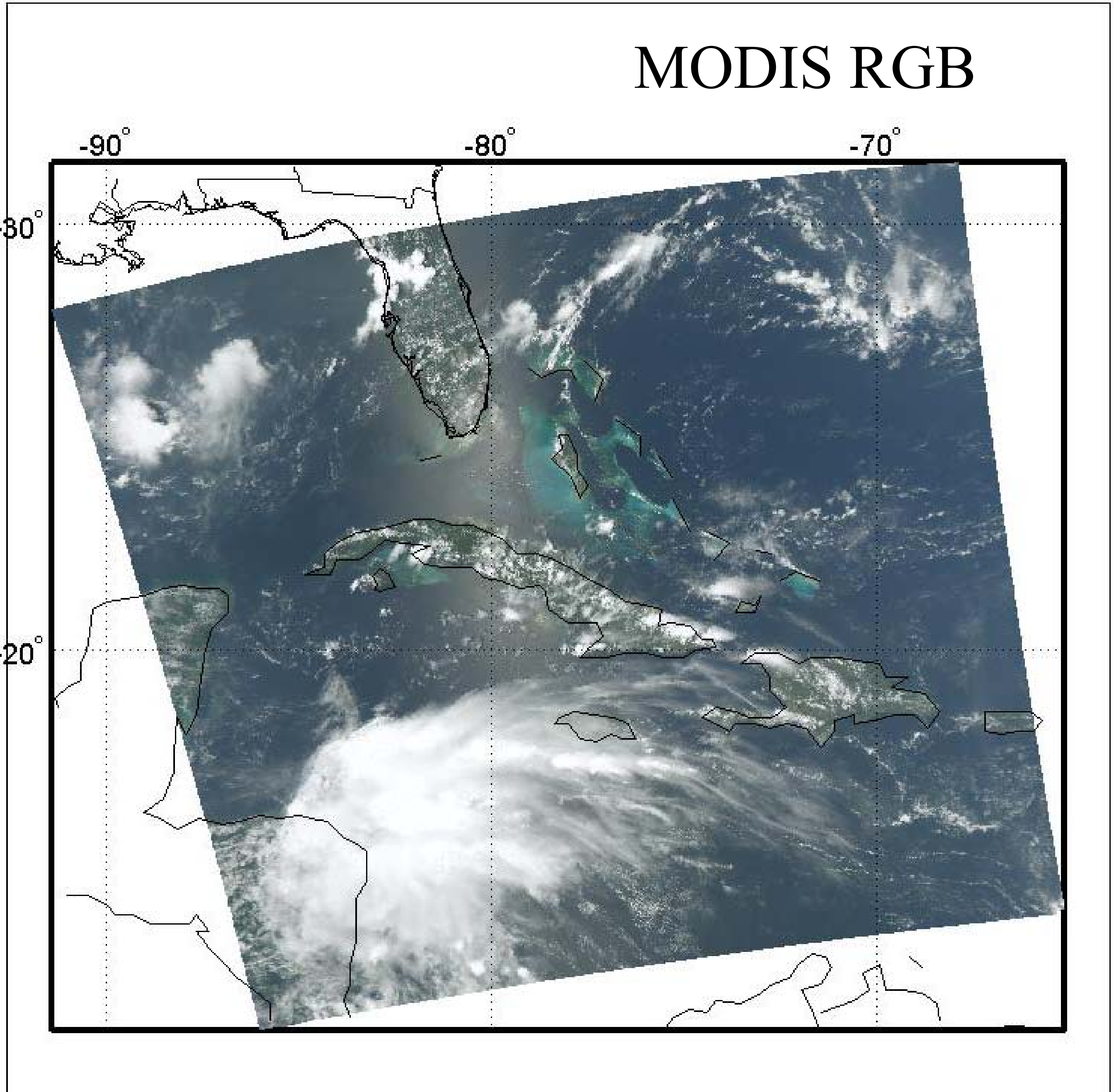


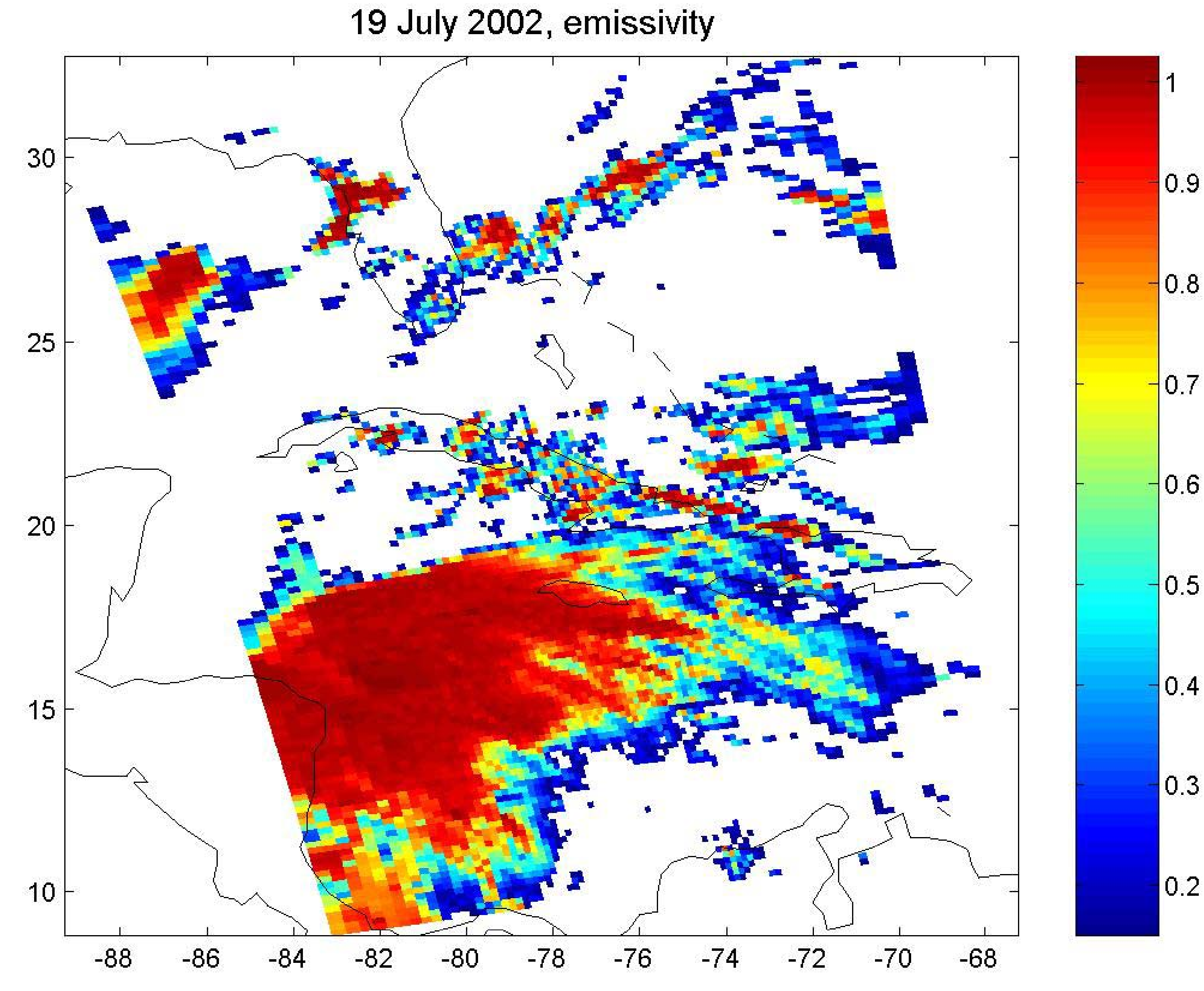

AIRS Example
19 July 2002
standard deviation of emissivity
mean emissivity
retrieved emissivity
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15



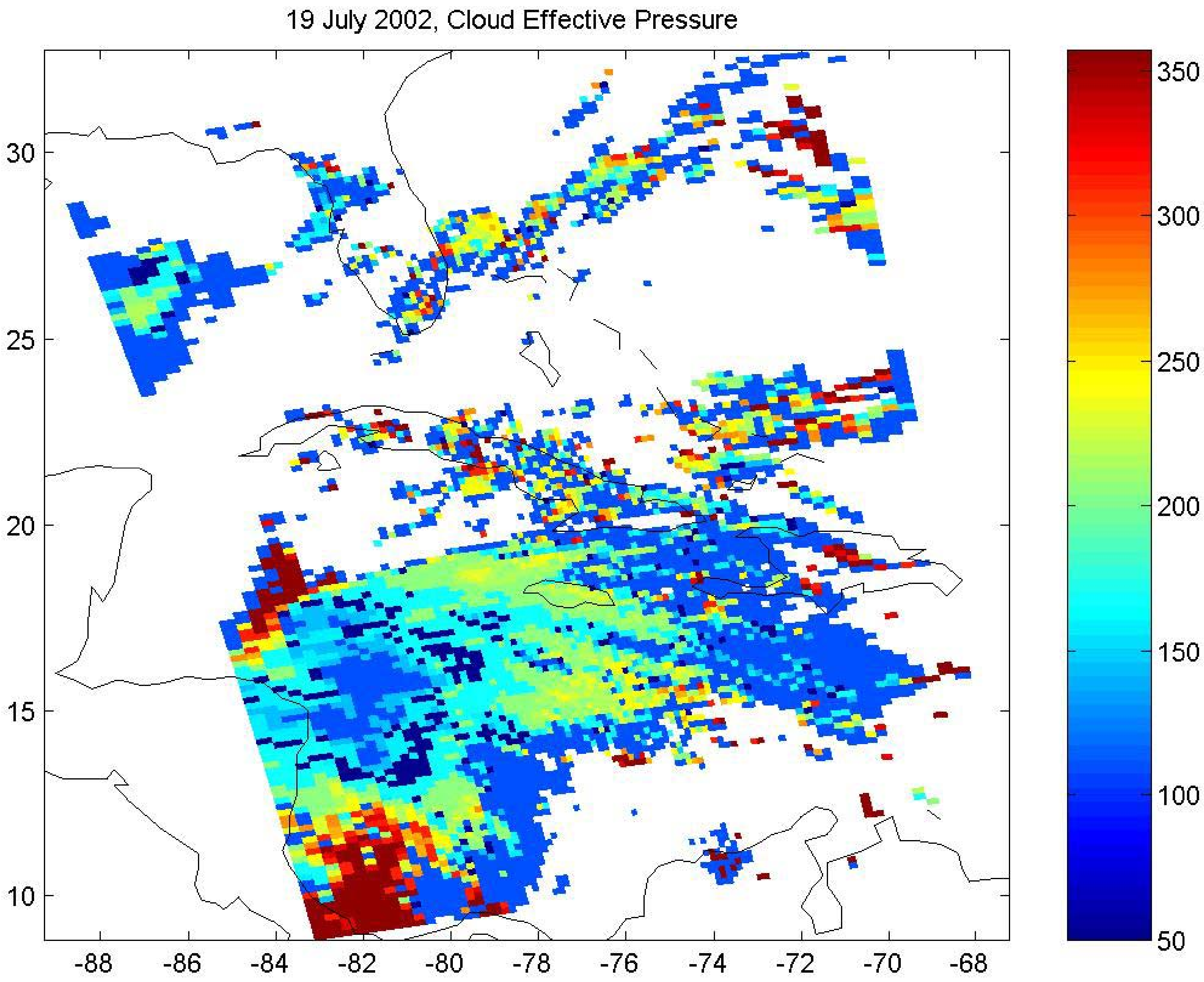
202848
202945
203051
Height [Km]
Time [HHMMSS]
HiCO2Slicing
MLEV
Lidar BS peak
Integrated BackScatter [ster-1]

July 19, 2002 Aqua

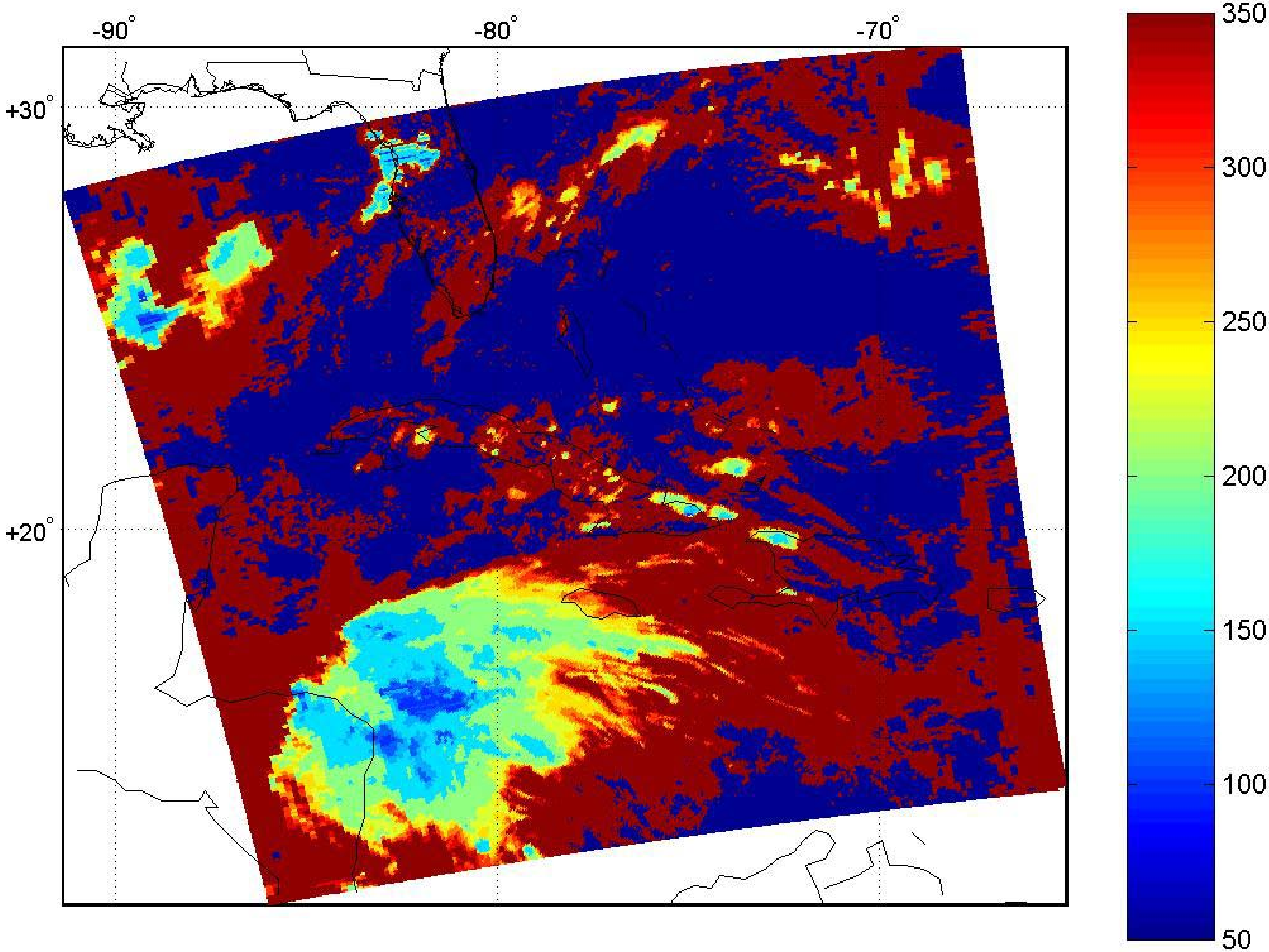


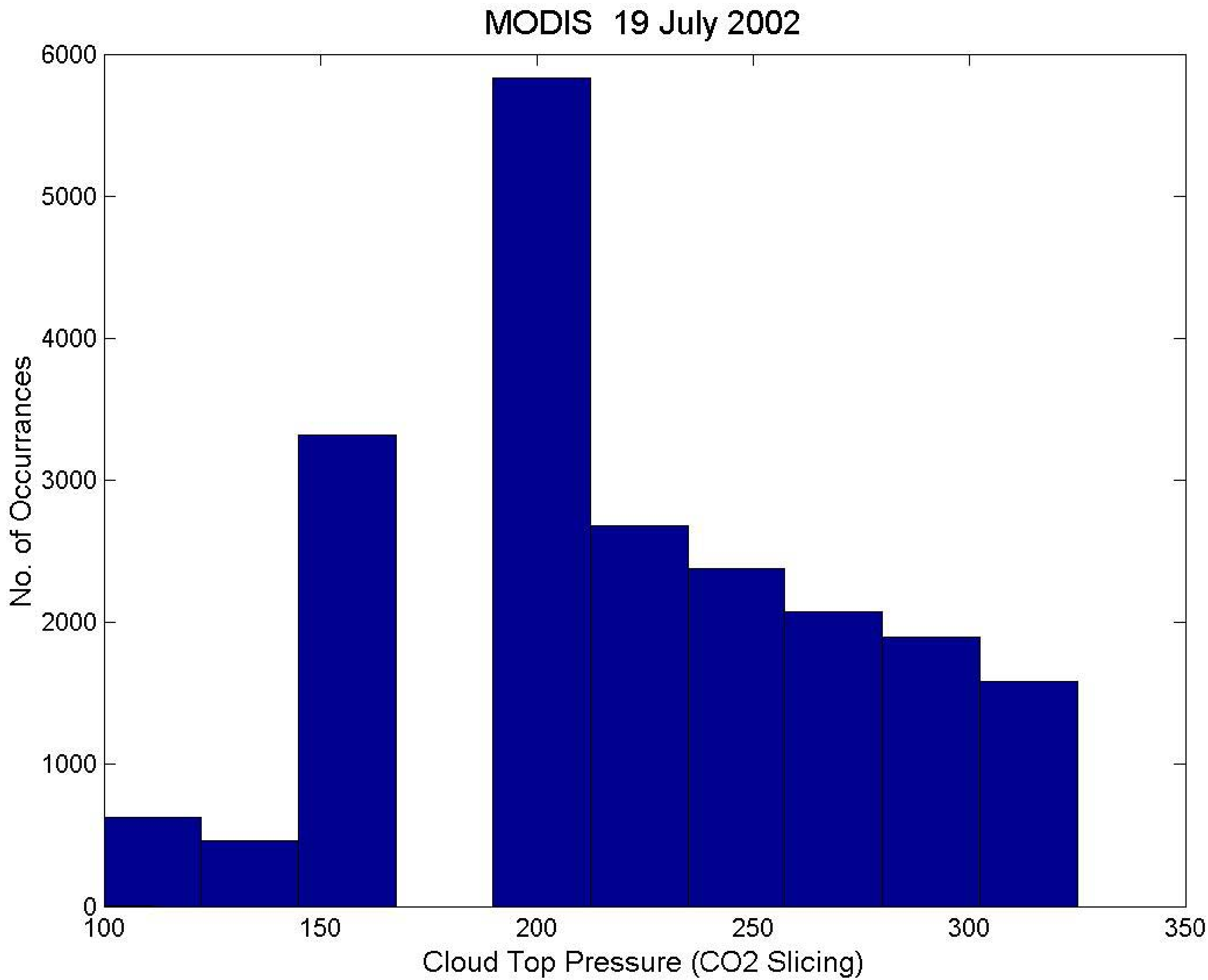


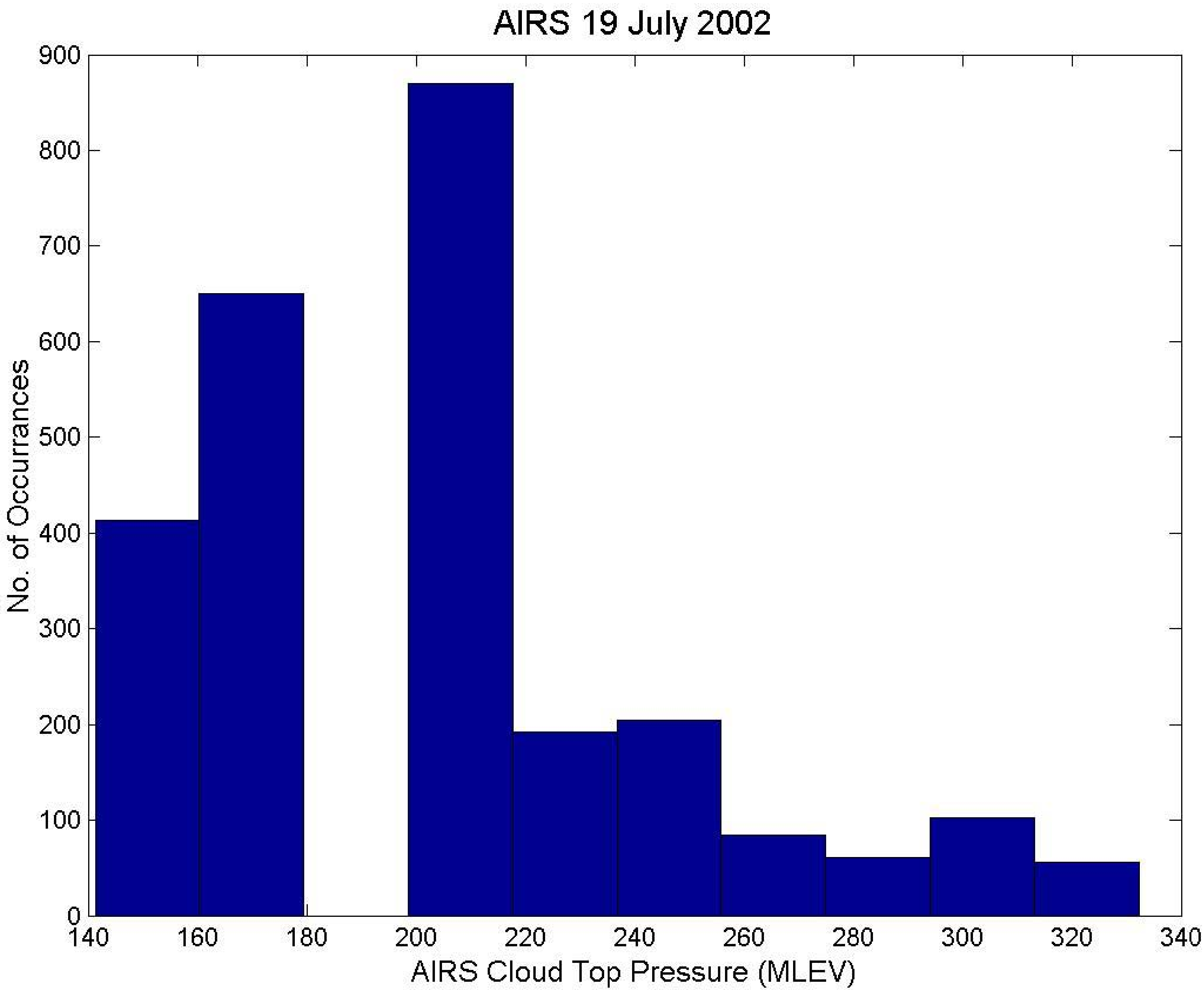
19 July 2002, emissivity
30
25
20
15
10
-88
-86
-84
-82
-80
-78
-76
-74
-72
-70
-68
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2


19 July 2002, Cloud Effective Pressure
30
25
20
15
10
-88
-86
-84
-82
-80
-78
-76
-74
-72
-70
-68
350
300
250
200
150
100
50

19 July 2002, Cloud Top Pressure (MODIS)



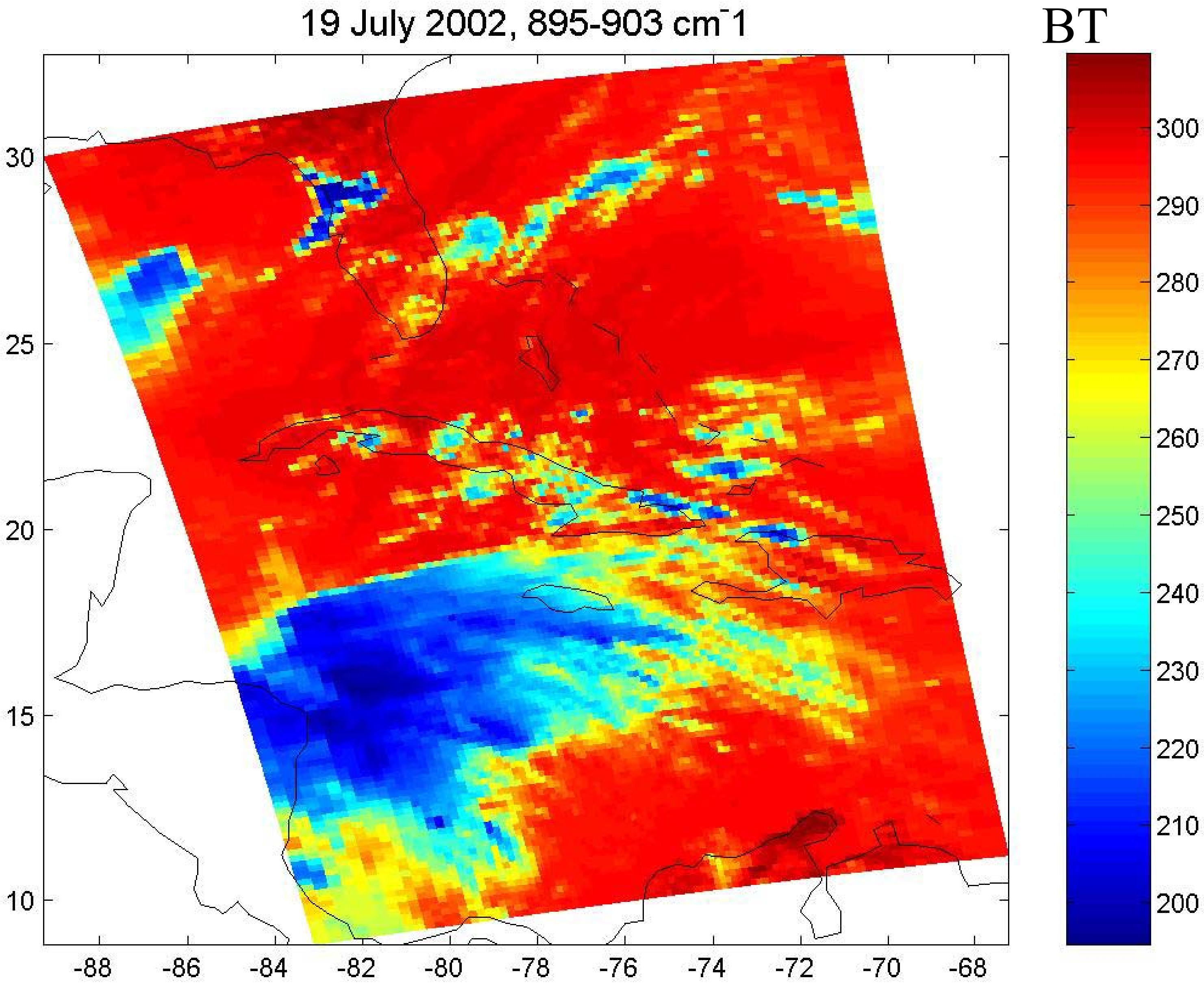

MODIS 19 July 2002
No. of Occurrances
Cloud Top Pressure (CO2 Slicing)
0
1000
2000
3000
4000
5000
6000
100
150
200
250
300
350


AIRS 19 July 2002
No. of Occurrances
AIRS Cloud Top Pressure (MLEV)
0
100
200
300
400
500
600
700
800
900
140
160
180
200
220
240
260
280
300
320
340

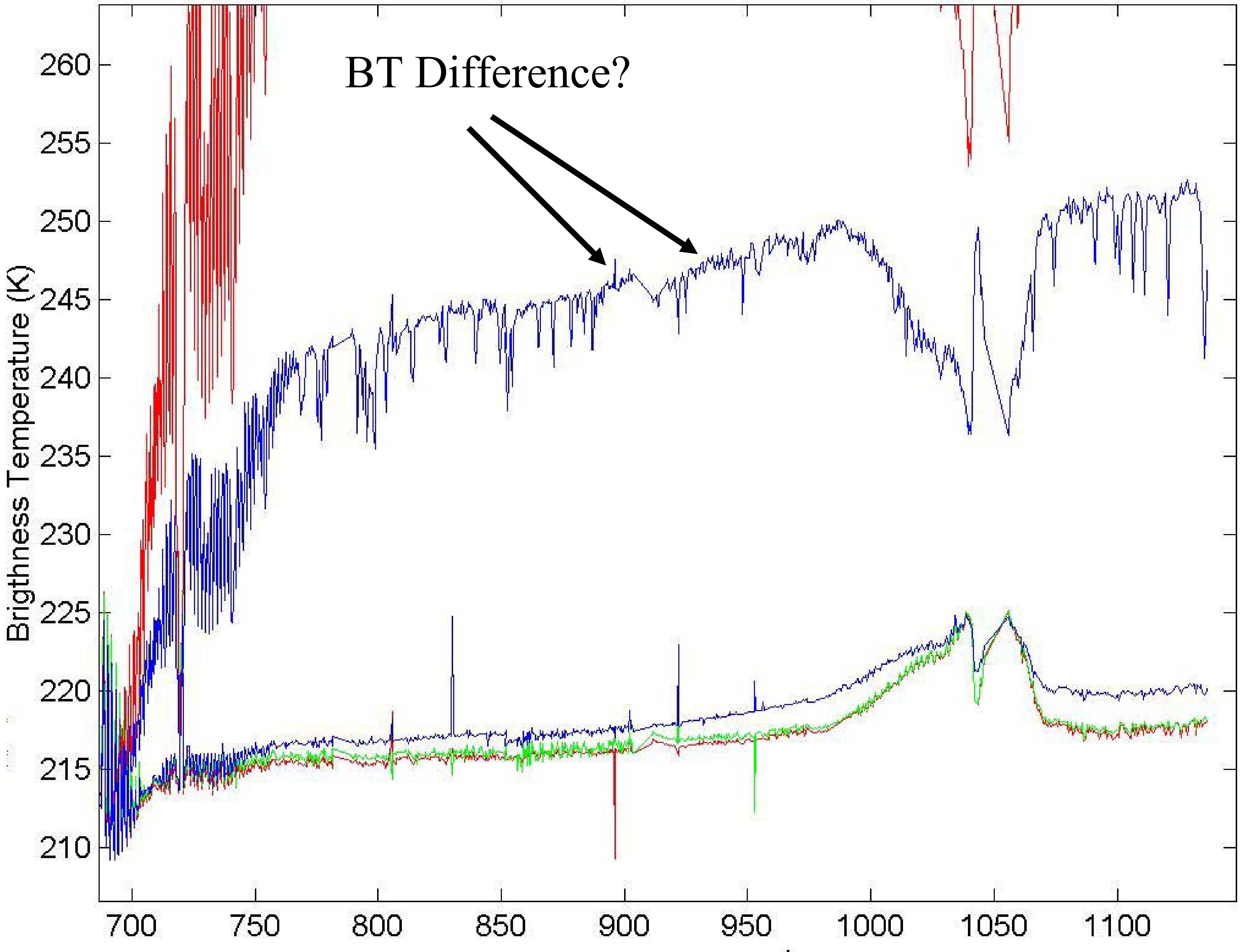
Combining Observations

- Collocation
- Radiance Comparisons
- Product Comparisons
- Combined Retrievals

AIRS

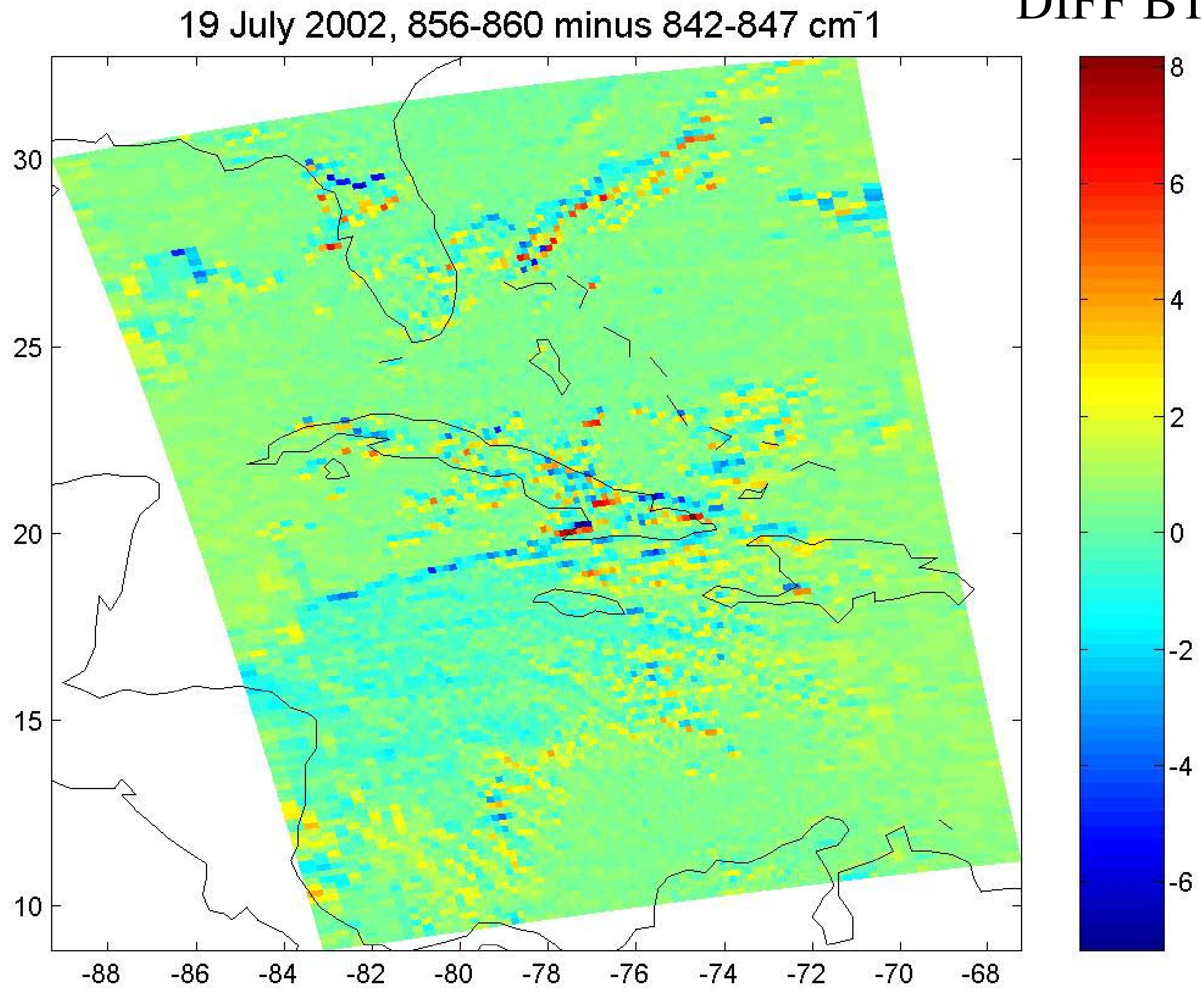

19 July 2002, 895-903 cm-1
BT
30
25
20
15
10
-88
-86
-84
-82
-80
-78
-76
-74
-72
-70
-68
300
290
280
270
260
250
240
230
220
210
200

19 July 2002 AIRS Spectra of clouds

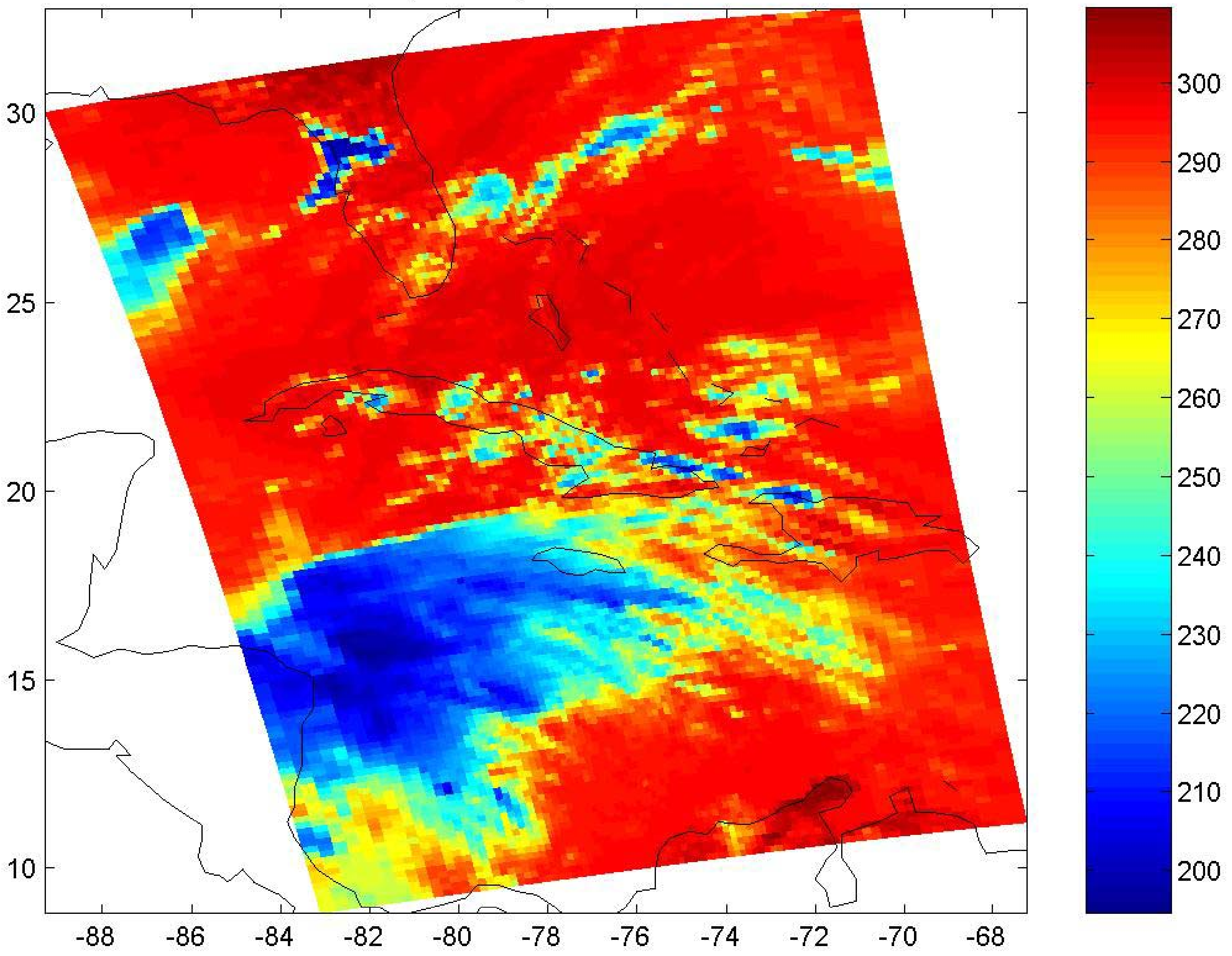


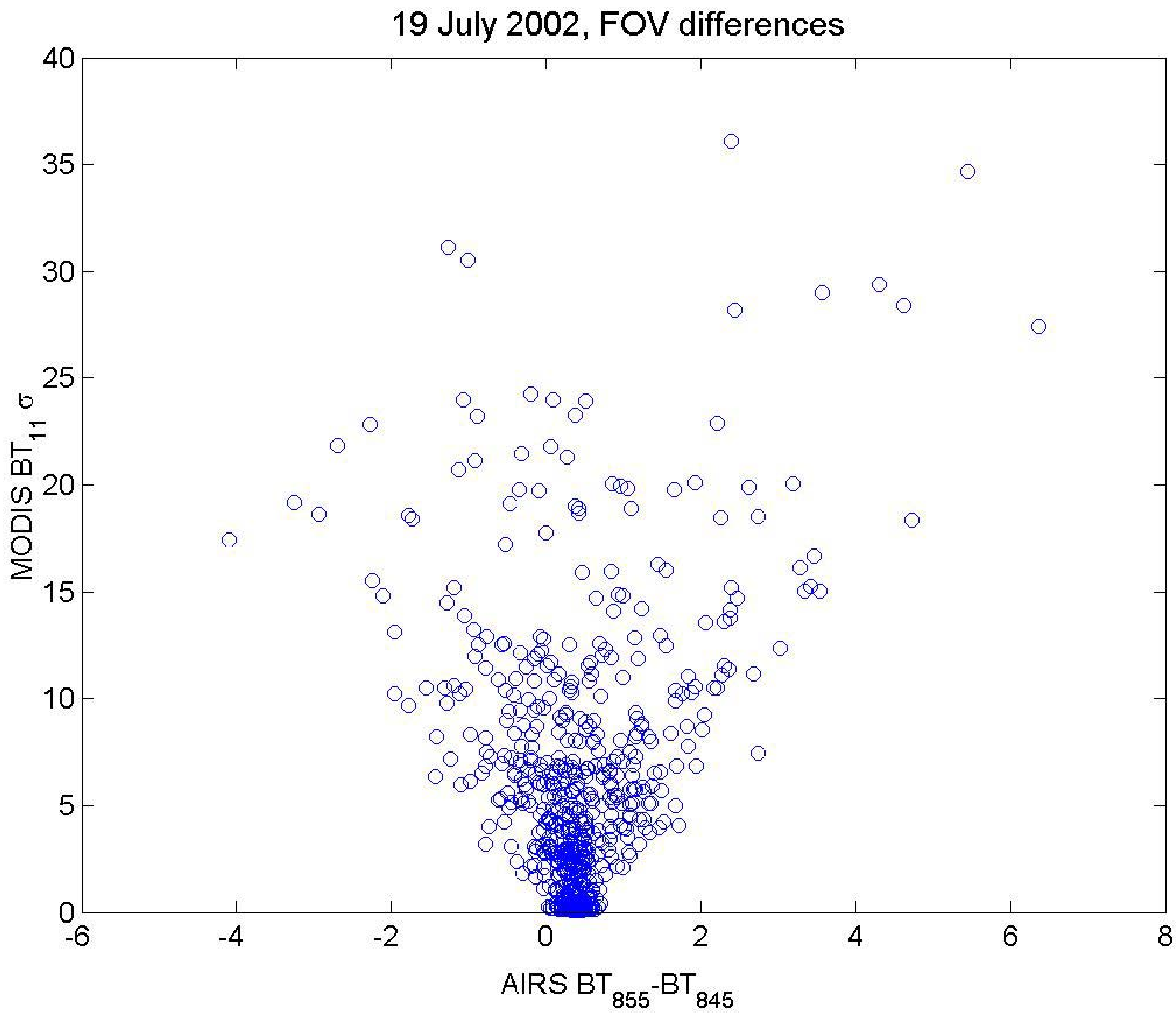
AIRS

DIFF BT


19 July 2002, 856-860 minus 842-847 cm-1
30
25
20
15
10
-88
-86
-84
-82
-80
-78
-76
-74
-72
-70
-68
8
6
4
2
0
-2
-4
-6

19 July 2002, 895-903 cm-1




19 July 2002, FOV differences
MODIS BT_{11} σ
AIRS BT_{855}-BT_{845}
40
35
30
25
20
15
10
5
0
-6
-4
-2
0
2
4
6
8

Summary

- Comparison of IR radiances
- Consistency between MODIS detection and AIR detection (ocean/daytime)
- Consistency in cloud properties (e.g. cloud top pressure)

Next Steps

- AIRS FOV differences in detectors leads to BT differences
- How to use MODIS to correct?